Effects of a Killed-Cover Crop Mulching System on Sweetpotato Production, Soil Pests, and Insect Predators in South Carolina

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ABSTRACT Sweetpotatoes, *Ipomoea batatas* (L.) Lam. (Convolvulaceae), are typically grown on bare soil where weeds and erosion can be serious problems. Conservation tillage systems using cover crop residues as mulch can help reduce these problems, but little is known about how conservation tillage affects yield and quality of sweetpotato or how these systems impact populations of beneficial and pest insects. Therefore, field experiments were conducted at the U.S. Vegetable Laboratory, Charleston, SC, in 2002–2004 to evaluate production of sweetpotatoes in conventional tillage versus a conservation tillage system by using an oat (*Avena sativa* L. (Poaceae)–crimson clover (*Trifolium incarnatum* L.) (Fabaceae) killed-cover crop (KCC) mulch. The four main treatments were 1) conventional tillage, hand-weeded; 2) KCC, hand-weeded; 3) conventional tillage, weedy; and 4) KCC, weedy. Each main plot was divided into three subplots, whose treatments were sweetpotato genotypes: 'Ruddy', which is resistant to soil insect pests; and 'SC1149-19′ and 'Beauregard', which are susceptible to soil insect pests. For both the KCC and conventional tillage systems, sweetpotato yields were higher in plots that received hand weeding than in weedy plots. Orthogonal contrasts revealed a significant effect of tillage treatment (conventional tillage versus KCC) on yield in two of the 3 yr. Ruddy remained resistant to injury by soil insect pests in both cropping systems; and it consistently had significantly higher percentages of clean roots and less damage by wireworm-*Diabrotica-Systena* complex, sweetpotato flea beetles, grubs, and sweetpotato weevils than the two susceptible genotypes. In general, injury to sweetpotato roots by soil insect pests was not significantly higher in the KCC plots than in the conventionally tilled plots. Also, more fire ants, rove beetles, and carabid beetle were captured by pitfall traps in the KCC plots than in the conventional tillage plots during at least 1 yr of the study. This study suggests that a sweetpotatoes can be successfully grown under a killed-cover crop production system.

KEY WORDS conservation tillage, pitfall traps, no-till, *Ipomoea batatas*

Sweetpotato, *Ipomoea batatas* (L.) Lam. (Convolvulaceae), is a vital staple food crop in much of the developing world (Woolfe 1992, Scott et al. 2000). It also is an important specialty crop in the United States (Dukes et al. 1992, USDA 2007b), where consumers prefer sweetpotatoes with sweet, moist-orange flesh (LaBonte and Cannon 1998). In the southern United States, sweetpotatoes are often grown on highly erodible soils (Bloodworth and Lane 1994), and conventional production procedures require multiple tillage operations such as plowing, disking, bedding, and cultivation (Wilson et al. 1989). The raised beds used in sweetpotato culture are typically formed from bare, tilled soil. Because unrooted sweetpotato cuttings are planted directly into these loose tilled beds, there is a high probability of erosion before the expanding root system and canopy stabilize the soil (Kays 1985). Conventional tillage practices for sweetpotato have other disadvantages, such as adversely affecting soil structure, accelerating carbon loss, enhancing evapotranspiration, enhancing weed growth, and requiring high nonrenewable energy inputs (Fox et al. 1991, Shrestha et al. 2006).

Sweetpotato growers often cultivate three to four times per season, but weed control is difficult because of the vinelike growth habit of sweetpotato and because there are few registered herbicides for this crop (Toth et al. 1996, Seem et al. 2003). Weed management by herbicides and cultivation has become increasingly more expensive as fuel costs rise. Expensive, hand weeding is also common in most sweetpotato production areas (Toth et al. 1996). Despite these early-season problems, sweetpotato does an excellent job of preventing soil erosion and sup-

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pressing weeds after the crop is established and its canopy is closed (Eke et al. 1990, Seem et al. 2003).

Conservation tillage systems offer an alternative to conventional practices that contribute to soil erosion and excessive production costs associated with weed control (Kuepper 2001). Cover crops provide many advantages, including erosion control, reduction in surface water pollution, added organic matter, reduction in carbon loss, improved soil structure and tilth, conservation of nitrogen resources, and weed control (Hartwig and Ammon 2002). Winter cover crops improve soil and water quality (Dabney et al. 2001). Use of crop mulches have been shown to reduce weed competition in vegetable crops (Hoyt et al. 1994, Creamer et al. 1996, Hoyt 1999, Abdul-Baki et al. 1999, Pullaro et al. 2006). Crop residue mulches suppress weed seed germination by limiting light penetration (Facelli and Pickett 1991; Teasdale and Mohler 1993, 2000) and by mechanically preventing emergence (Creamer et al. 1996). Killed-cover crop (KCC) mulches also reduce evapotranspiration and increase soil water retention (Teasdale and Mohler 1993, Jett 1999) and prevent soil erosion (Seta et al. 1993). Conservation tillage systems with cover crops helps promote year-long natural enemy and pest species interactions by providing alternate food sources and protection from adverse conditions (Tillman et al. 2004). Also, some cover crops, such as rye (*Secale cereale* L.) (Poaceae) and crimson clover (*Trifolium incarnatum* L.) (Fabaceae), have allelopathic effects on weed germination (Barnes and Putnam 1983, Creamer et al. 1996).

Sweetpotatoes that were grown under a conservation tillage system in Mississippi produced similar yields to conventionally tilled sweetpotatoes (Bloodworth et al. 1995). In these experiments, cover crops of crimson clover, hairy vetch (*Vicia villosa* Roth), rye, or wheat (*Triticum aestivum* L.) helped decrease soil erosion, conserve soil moisture, and decreased weed competition, while not affecting yields. A simple adaptation to a conventional planter was used in the transplantation of sweetpotato slips into heavy residue plots (Edwards et al. 1998). Jett (1999) reported that sweetpotatoes grown in an undisturbed rye residue in Louisiana had a significantly greater leaf area, vine weight, root set, and yield relative to conventionally tilled sweetpotatoes, which was attributed to lower soil temperatures that increased root set. However, in one experiment, white grubs, *Phyllophaga ephilida* Say, were higher in the conservation tillage plots (Jett and Talbert 1997). Stone et al. (2005) reported that in northern Alabama, the highest yields of 'Beauregard' sweetpotatoes were produced from killed-cover crop treatments of crimson clover or hairy vetch. In North Carolina, organic sweetpotatoes grown in a cover crop with reduced tillage had yields similar to sweetpotatoes grown organically with conventional tillage (Treadwell 2005). Cover crop treatments influenced weed density, biomass, and crop yield in organically managed sweetpotato systems (Treadwell et al. 2007).

Sweetpotato production is limited by several insect pests (Cuthbert 1967, Schalk and Jones 1985, Chalfant et al. 1990), and improved pest management approaches for this crop are needed (Schalk et al. 1991, Jackson et al. 2002). The primary soil insect pests of sweetpotato in the United States are spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber (Coleoptera: Chrysomelidae); banded cucumber beetle, *D. balteata* LeConte (Coleoptera: Chrysomelidae); sweetpotato flea beetle, *Chaetocenema confinis* Crotch (Coleoptera: Chrysomelidae); elongate flea beetle, *Systena elongata* (F.) (Coleoptera: Chrysomelidae); wireworm larvae (*Conoderus* spp.) (Coleoptera: Elateridae); white grub larvae (*Phyllophaga* spp.) and *Plectris aliena* Chapin (Coleoptera: Scarabaeidae); and sweetpotato weevil, *Cylas formicarius* (F.) (Coleoptera: Brentidae) (Cuthbert 1967, Schalk and Rolston 1992). Management of insect pests of sweetpotato has relied on chemical insecticides and cultural practices (Chalfant et al. 1990, Schalk et al. 1991). However, control of insects with insecticides can be expensive and unreliable, and it may cause environmental or safety concerns. In some instances, chemical insecticides fail to provide adequate protection to roots, and losses due to insects can exceed 50%, especially in countries where low-input agricultural systems predominate (Jackson et al. 2002). Effective, low-input, environmentally benign integrated pest management approaches are needed as alternatives to chemical pest control (Schalk et al. 1993).

Conservation tillage systems influence insect abundance (Stinner and House 1990; Hummel et al. 2002a, 2002b). For example, populations of beneficial arthropod predators, such as carabid beetles, are enhanced by dense vegetation (Kromp 1999). Pullaro et al. (2006) found higher numbers of arthropod predators, including carabid beetles (Coleoptera: Carabidae), in a killed-cover crop system for bell peppers (*Caspium* spp.). However, red imported fire ants, *Solenopsis invicta* Buren (Hymenoptera: Formicidae), were the main predatory species. Higher numbers of fire ants were found in conservation tillage cotton than in conventional tillage cotton, and these predators helped reduce populations of lepidopteran larvae (Tillman et al. 2004).

The objectives of the study herein were to 1) determine the effect of a killed-cover crop production system on sweetpotato yield and quality, 2) assess weed suppression by a killed-cover crop mulch, 3) determine the effectiveness of insect-resistant and insect-susceptible sweetpotato varieties in a killed-cover crop production system, and 4) determine the effects of the killed-cover crop on predatory arthropods.

Materials and Methods

A KCC conservation tillage system for sweetpotato was evaluated in 2002–2004. In these experiments, a winter cover crop mixture of oats and crimson clover was killed in the late spring and left on the soil surface to serve as mulch. Each experiment was arranged in randomized complete block, split-plot design where the four main plot treatments were 1) killed-cover crop mulch that was hand-weeded (KCC-HW); 2) killed-cover crop mulch with no weed control (KCC-WE); 3) conventional tillage, hand-weeded (CT-HW); and (4) conventional tillage, weedy (CT-WE). Subplots were planted to one of three sweet, orange-flesh sweetpotato varieties 'Ruddy', 'SC1149-19', and 'Beauregard'.

Experiments were conducted at the USDA–ARS U.S. Vegetable Laboratory (USVL) (32° 78″ N, 80° 05″ W) during 2002, 2003, and 2004. Soil in these fields consisted of Hockley loamy fine sand and Yonges loamy fine sand, which are nearly level (0–2% slopes) soils found on the lower coastal plain of South Carolina. Hockley loamy fine sand is moderately well drained and moderately permeable. Yonges loamy fine sand is a poorly drained and slowly permeable soil (USDA 1971, 2007a). All fields had a pH of 6.0–6.4.

Fields used for the experiments were formed into narrow beds at 1-m spacing in the fall. The winter cover crop consisted of a mixture of crimson clover seeded at 44.8 kg/ha and oats seeded at 134.4 kg/ha. Glyphosate herbicide (Roundup, Monsanto, St. Louis, MO) was applied (2.2 kg/ha) to conventional tillage plots to reduce weed growth during the winter, and beds in the bare soil plots were reshaped before transplanting. Beds in the cover crop plots were not reshaped. The cover crops were killed with glyphosate (2.2 kg/ha) and the residue was mechanically flattened 2–3 wk before transplanting sweetpotatoes.

Subplots consisted of three adjacent rows within the nine-row main plots. Main plots were separated within rows by a 3-m bare-soil alley. Plots were 7.6 m long, and sweetpotato seedlings were spaced 30 cm apart within rows. Thus, each subplot consisted of three adjacent rows of 25 plants each of a particular sweetpotato genotype. There were six replications in 2002 and 2004, and five replications in 2003. Transplanting dates were 2 July 2002, 8 July 2003, and 8 June 2004. After transplanting, plots were fertilized with 1,000 lb/acre of 4–8-12. Missing plants were replaced within two weeks of initial transplanting. Weeded plots were hoed two or three times during the early growing season. No insecticides were applied to any of the fields before or during these experiments. The center row of each subplot (25 plants) was harvested on 12 November 2002 (133-d growing season), 5 November 2003 (122-d growing season), and 20 October 2004 (138-d growing season).

Beauregard [PI 566613 (USDA 2005)] is a high-yielding, sweet orange-fleshed cultivar that is presently the most widely grown sweetpotato in the United States (Rolston et al. 1987, Schultheis et el. 1999). Development of the leaf canopy varies among sweetpotato cultivars; thus, they are differentially affected by weed interference (LaBonte et al. 1999). Beauregard has a thinner canopy than many other commercial sweetpotato varieties (Harrison and LaBonte 2003, LaBonte et al. 2003, Yencho and Pecota 2007), and it is not very tolerant to weed competition (LaBonte et al. 1999). Seem et al. (2003) demonstrated that Beauregard had a critical weed-free period from 2 to 6 wk after transplanting. Beauregard has resistance to some diseases (Rolston et al. 1987); however, it is very susceptible to most insect pests (Thompson et al. 2001, Jackson et al. 2002). SC1149-19 [PI 634401 (USDA 2005)] is a sweet, orange-fleshed genotype that is highly susceptible to soil insect pests, nematodes, and diseases (Jackson et al. 2002). It was developed by the USDA–ARS/Clemson University sweetpotato-breeding program using the mass selection breeding technique and sent to the National Plant Germplasm System in 1987 (USDA 2005). This genotype has been used for several years as a susceptible standard control for field evaluations of resistance of sweetpotato breeding materials (Jones et al. 1979, 1987; Schalk et al. 1986, 1993; Jackson and Bohac 2006). Ruddy is a relatively new release from the USDA–ARS/Clemson University sweetpotato-breeding program (USDA 1999) that is highly resistant to damage by soil insect pests, *Fusarium* wilt, and southern root-knot nematodes (*Meloidogyne incognita*, races 1 and 3) (Bohac et al. 2002).

After harvest, roots were cured, washed, graded, weighed, and then examined for injury by soil insect pests. The total weight and number of roots in each plot were determined. All individual roots were scored for insect damage by previously published procedures (Schalk et al. 1991, Jackson et al. 2002). Among the parameters calculated was the severity index for the wireworm, *Diabrotica*, *Systena* complex (WDS) (Cuthbert and Davis 1971). WDS severity index was calculated by averaging the rating given to each root (1, 1–5 holes or scars; 2, 6–10 holes or scars; 4, >10 holes or scars). Injury by white grubs, sweetpotato flea beetles, and sweetpotato weevils were the percentages of total roots that showed any damage by these insects. The percentages of uninjured roots (undamaged by any of the soil insect pests) also were determined for each entry.

Pitfall traps (BioQuip Products, Rancho Dominguez, CA) were monitored in 2003 and 2004. These traps consist of two white plastic containers (7.6 by 11.4 cm). They were placed in the ground so that the rim was flush with the soil surface. The upper container was lifted out to remove specimens and clean and the bottom container remained in the ground. A white plastic top (26 cm in diameter) was secured over the collection chambers to provide shade and protection from rainfall. This cover was secured by three 16 penny nails and was ≈2 cm above the ground. Traps were filled to a depth of ≈3 cm with soapy water. The soapy water contained 5 ml of liquid Ultra Palmolive Antibacterial Hand Soap (Colgate-Palmolive Company, New York, NY) per liter of tap water. One trap was placed in the middle of the center row of each whole plot. Thus, there were 20 traps (four treatments × 5 replications) in 2003, and 24 traps (four treatments × 6 replications) in 2004. Pitfall traps were placed in the field on 12 June, 15 June, 26 June, 6 July, 14 July, 21 July, 24 July, 28 July, 1 August, 8 August, 11 August, 28 August, 6 September, 14 September, 21 September, 25 September, and 10 October 2003. They

Table 1. *F* values from ANOVA (PROC MIXED, SAS Institute 1999) for average weights, number of roots, average root weight, and soil insect damage for 3 yr (2002–2004) for four tillage treatments (CT-WE, KCC-WE, CT-HW, and KCC-HWE), and three sweetpotato genotypes (Beauregard, Ruddy, and SC1149-19) in field experiments at the USVL, Charleston, SC

Source of variation	df, numerator	df, denominator	Wt (kg)	Wt per root	No. roots	% undamaged roots	WDS index	% flea beetle damage	% grub damage	% weevil damage
2002										
Tillage treatment (main plot)	3	15	15.1**	5.7**	16.4**	5.8*	5.7*	5.0*	1.8	2.3
Sweetpotato genotype (subplot)	2	40	13.5**	7.2**	12.5**	88.1**	43.6**	28.1**	23.9**	19.9**
Replication	5	15	5.4**	7.2**	2.3	2.3	4.3*	1.8	0.4	1.7
Treatment × genotype	6	40	2.7	1.9	2.5	0.9	0.7	0.7	1.1	1.4
Contrast: conventional vs. KCC	1	15	1.6	0.3	2.8	4.9*	6.4*	9.1**	3.6	1.4
Contrast: weedy vs. hand weeded	1	15	33.8**	10.5**	37.6**	0.3	1.3	0.0	0.1	3.2
2003										
Tillage treatment	3	12	8.1**	8.1**	3.7*	0.2	0.6	0.3	1.4	0.2
Sweetpotato genotype	2	32	9.0**	15.7**	3.0	114.6**	27.1**	42.6**	5.6**	104.6**
Replication	5	12	3.4*	4.7*	2.4	2.3	2.2	0.9	1.0	0.4
Treatment × genotype	6	32	1.1	1.4	1.3	0.9	1.0	0.5	1.2	0.2
Contrast: conventional vs. KCC	1	12	8.4*	5.4*	3.4	0.1	1.5	0.0	0.8	0.0
Contrast: weedy vs. hand weeded	1	12	14.5**	16.6**	7.4*	0.5	0.1	0.1	3.3	0.4
2004										
Tillage treatment	3	15	52.5**	64.0**	17.9**	33.1**	16.2**	5.5**	10.1**	0.1
Sweetpotato genotype	2	40	0.1	16.8**	7.9**	334.9**	67.2**	34.0**	60.9**	9.2**
Replication	5	15	1.7	2.2	1.5	0.6	1.4	1.6	2.9	2.4
Treatment × genotype	6	40	0.9	6.8**	1.7	8.9**	5.1**	2.3	2.6	0.1
Contrast: conventional vs. KCC	1	15	15.3**	41.8**	0.1	32.6**	15.3**	1.5	1.3	0.0
Contrast: weedy vs. hand weeded	1	15	137.3**	149.5**	52.1**	48.9**	32.1**	14.8*	25.3**	0.0

* Significant at the 5% level.
** Significant at the 1% level.

were monitored on 18 June, 24 June, 1 July, 8 July, 15 July, 22 July, 5 August, 19 August, 9 September, 16 September, and 23 September 2004. Traps were collected after 3 d. When not being used, traps were covered with a plastic lid to prevent invertebrates from being captured inadvertently. Trap collections were placed into plastic bags and placed in the freezer (−18°C) until they could be analyzed. All invertebrates were identified and counted.

Because fire ant mounds were numerous in and around our experimental fields yet few ants were collected in pitfall traps, their populations were estimated using screw-capped glass scintillation vials (20 ml) baited with a small piece of hot dog (Carolina Pride Wieners, Greenwood, SC) (Pullaro et al. 2006). Baited vials were laid on their side in each plot near each pitfall trap. Vials were left in the field for ≈1 h. Vials were collected and capped in the same order in which they were set out so sampling time was approximately equal. Vials were placed in the freezer (−18°C) for at least 24 h to kill ants before counting them. Fire ants were monitored on 27 June, 21 July, and 9 August 2003 and on 8 July, 17 July, 19 August, and 1 September 2004.

Yield and insect injury data for each year were subjected to analysis of variance (ANOVA) as a split-plot design (Littell et al. 1996, PROC MIXED, SAS Institute 1999). Because only one pitfall trap or vile for capturing fire ants was sampled from each main plot (i.e., no subplot sampling), these data were not analyzed as a split-plot design. Instead, the effects of sweetpotato genotype were ignored for this ANOVA, and only main plot effects were considered (PROC GLM, SAS Institute 1999). Because of a highly skewed distribution, fire ant data were transformed (log + 1.0) before ANOVA. For all parameters, orthogonal comparisons were made between tillage treatments (conventional versus KCC) and between weed treatments (weedy versus hand-weeded). Treatment means for yield (kilograms), number of roots, average root weight, percent undamaged roots, WDS index, percentage of flea beetle damage, percentage of grub damage, percentage of sweetpotato weevil damage, fire ant captures, and collections from pitfall traps were separated by Fisher' least significant difference (LSD) at the 5% probability level for type I errors (PROC GLM, SAS Institute 1999).

Results

ANOVA for each year showed that there were significant effects of main plot treatments on total root weight (kilograms), average root weight, and numbers of roots (Table 1). Effects of genotype (subplot) on average root weight were significant each year; however, effects of genotype on total yield were only significant in 2002 and 2003, and effects of genotype on numbers of roots were only significant in 2002 and

Table 2. Average weights, number of roots, and soil insect infestations in four tillage treatments averaged for three sweetpotato genotypes at the USVL, Charleston, SC, 2002–2004

Treatment	Wt (kg)	Wt per root (kg)	No. roots	% undamaged roots	WDS index	% flea beetle damage	% grub damage	% weevil damage
2002								
Killed-cover crop hand weeded (KCC-HW)	10.7ab	0.19a	115.8a	63.7ab	0.46ab	5.8b	6.6 ns	2.3 ns
Conventional tillage hand weeded (CT-HW)	12.3a	0.22a	124.6a	55.4b	0.53a	11.3a	7.7	3.6
Killed-cover crop weedy (KCC-WE)	8.5b	0.19a	94.6b	65.0a	0.36b	5.8b	5.0	1.1
Conventional tillage weedy (CT-WE)	4.8c	0.15b	63.3c	58.0ab	0.50ab	11.0a	10.6	1.5
2003								
Killed-cover crop hand weeded (KCC-HW)	2.7b	0.10b	59.3ab	59.1 ns	0.28 ns	7.2 ns	2.0 ns	16.9 ns
Conventional tillage hand weeded (CT-HW)	4.1a	0.12a	72.5a	59.7	0.25	8.4	3.2	17.6
Killed-cover crop weedy (KCC-WE)	1.7b	0.08b	46.3b	61.4	0.27	7.8	0.8	16.4
Conventional tillage weedy (CT-WE)	2.3b	0.09b	54.3b	63.2	0.23	6.6	1.1	15.1
2004								
Killed-cover crop hand weeded (KCC-HW)	15.1a	0.14a	112.4a	37.0b	0.90a	16.6a	22.6a	2.0 ns
Conventional tillage hand weeded (CT-HW)	10.1b	0.11b	100.7a	40.7b	0.72ab	14.8a	24.2a	2.7
Killed-cover crop weedy (KCC-WE)	3.8c	0.07c	48.7b	43.8b	0.60b	8.4b	16.2b	2.4
Weedy (CT-WE)	2.5c	0.04d	55.0b	68.1a	0.23c	4.1b	9.9c	2.0

Within each year, means in the same column followed by the same letter are not significantly different according to Fisher's LSD at the 5% probability level (SAS Institute 1999); ns, not significant.

2004. Tillage × genotype interactions were significant for yield and number of roots in 2002, and for average root weight in 2004. There were significant replication effects on total root weight and average root weight in 2002 and 2003. Orthogonal comparisons of tillage treatments (conventional versus KCC) were significant for total root weight and average root weight in 2003 and 2004, and for number of roots in 2003 (Table 1). Orthogonal comparisons of weed treatments (weedy versus hand-weeded) were significant for total root weight, number of roots, and average root weight each year.

The effects of main plot treatments on insect damage were significant for percentage of clean roots, WDS index, and percentage of flea beetle damage in 2002 and 2004, and for percentage of grub damage in 2004 (Table 1). Main plot treatments had no significant effects on soil insect data in 2003. Effects of genotype (subplot) on percentage of undamaged roots, WDS index, percentage of flea beetle damage, percentage of grub damage, and percentage of weevil damage were significant each year. Tillage × genotype interactions were only significant for percentage of clean roots and WDS index in 2004. Replication effects were significant for WDS index in 2002. Orthogonal comparisons of tillage treatments were significant for percentage of clean roots and WDS index in 2002 and 2004, and for percentage of flea beetle damage in 2002 (Table 1). Orthogonal comparisons of weed treatments were significant for percent undamaged roots, WDS index, percentage of flea beetle damage, and percentage of grub damage only in 2004.

Total root weight, average root weight, and number of roots were significantly higher in CT-HW than in CT-WE each year (Table 2). In 2002 and 2004, numbers of roots were significantly higher in KCC-HW than in KCC-WE, but only in 2004 did hand weeding positively affect total root weight and average root weight in the killed-cover crop plots. Only in 2002 were yields in the KCC-WE plots higher than in the CT-WE plots. In the other 2 yr, there were no differences in yields between the KCC-WE and CT-WE plots, indicating that weed suppression provided by the mulch may have helped reduce the effect of weed interference on yields (Table 2). KCC-HW out yielded CT-HW in 2004, CT-HW outyielded KCC-HW in 2003, and there was no difference between these treatments in 2002.

Although the percentages of undamaged roots were numerically higher in the KCC plots in 2002, these differences were only significant between KCC-WE and CT-HW (Table 2). In 2002, percentage of flea beetle damage was significantly lower in both KCC treatments compared with the conventionally tilled plots. However in 2004, weed control had a bigger influence on insect damage than did tillage treatment, in which the hand-weeded plots had a significantly higher percentage of flea beetle damage, WDS index, and percentage of grub damage than the weedy plots of the same tillage treatment.

Overall, SC1149-19 produced significantly more storage roots and total yield than the other two varieties (Table 3). The insect resistance of Ruddy held up well under the killed-cover crop conditions, and it had higher percentage of clean roots and less damage by WDS, sweetpotato flea beetles, grubs, and sweetpotato weevils than the two susceptible genotypes.

ANOVA for the 2003 pitfall trap and fire ant data showed that there were significant treatment effects for captures of crickets (Orthoptera: Gryllidae), small

Table 3. Three-year average weights, number of roots, and soil insect damage in four tillage treatments of three sweetpotato genotypes at the USVL, Charleston, SC, 2002–2004

Treatment	Wt (kg)	No. roots	% undamaged roots	WDS index	% flea beetle damage	% grub damage	% weevil damage
SCll49-19 (highly susceptible)							
Killed-cover crop hand weeded (KCC-HW)	12.4a	130.2a	29.3ab	0.823a	17.8ab	17.8ab	14.9 ns
Conventional tillage hand weeded (CT-HW)	9.5b	111.3a	24.7b	0.761a	22.9a	14.6ab	17.9
Killed-cover crop weedy (KCC-WE)	6.0c	75.7b	30.9ab	0.694ab	16.3ab	9.4b	14.9
Conventional tillage weedy (CT-WE)	3.3d	59.5b	36.7a	0.521b	13.9b	11.4b	14.8
Beauregard (susceptible)							
Killed-cover crop hand weeded (CT-HW)	8.9a	75.1ab	39.8c	0.779a	11.4a	17.2a	4.2 ns
Conventional tillage hand weeded (CT-HW)	10.1a	89.2a	44.6bc	0.655ab	9.7ab	15.7ab	4.0
Killed-cover crop weedy (KCC-WE)	3.6b	50.1c	51.5ab	0.475bc	5.3b	11.9ab	3.0
Conventional tillage Weedy (CT-WE)	3.9b	60.8bc	60.7a	0.380c	6.9ab	10.6b	1.7
Ruddy (resistant)							
Killed-cover crop hand weeded (KCC-HW)	8.4a	88.6a	89.6 ns	0.085 ns	0.9b	0.9ab	0.3 ns
Conventional tillage hand weeded (CT-HW)	7.3a	97.8a	86.0	0.096	2.1a	2.4a	0.5
Killed-cover crop weedy (KCC-WE)	5.0b	66.9b	87.0	0.088	0.3b	1.9ab	0.2
Conventional tillage weedy (CT-WE)	2.4c	52.8b	92.0	0.072	1.1b	0.6b	0.5

Within each sweetpotato genotype, means in the same column followed by the same letter are not significantly different according to Fisher's LSD at the 5% probability level (SAS Institute 1999); ns, not significant.

ground beetles (Coleoptera: Carabidae), scarab beetles (Coleopotera: Scarabaeidae), tiger beetles (Coleoptera: Cicindelidae), and total insects (Table 4). There were no significant replication or treatment × replication interaction effects for any of the pitfall trap or fire ant data in 2003. Orthogonal comparisons of tillage treatments were significant for captures of crickets, small ground beetles, and tiger beetles. Orthogonal comparisons of weed treatments were significant for scarab beetles and total numbers of invertebrates captured in the pitfall traps.

ANOVA for the 2004 pitfall trap and fire ant data showed that there were significant treatment effects for captures of fire ants, crickets, click beetles (Coleoptera: Elateridae), large ground beetles, rove beetles (Coleoptera: Staphylinidae), tiger beetles, and total insects (Table 4). There were no significant replication or treatment × replication interaction effects for any of the pitfall trap or fire ant data in 2004. Orthogonal comparisons of tillage treatments were significant for captures of crickets, click beetles, rove beetles, large ground beetles, and tiger beetles. Orthogonal comparisons of weed treatments were significant for fire ants, crickets, large ground beetles, and total numbers of invertebrates captured in the pitfall traps.

More predatory fire ants, rove beetles, and small carabid beetles were captured by pitfall traps in the KCC plots than in the conventional tillage plots during at least 1 yr of the study (Table 5). However, nearly all of the tiger beetle predators were captured in the conventionally tilled plots both years. In 2004, more large ground beetles were captured in the conventionally tilled, weedy plots than in the other treatments. Many of these large carabids are seed predators, which could explain there greater presence in the

Table 4. *F* values from ANOVA (PROC GLM, SAS Institute 1999) for pitfall traps and fire ant monitoring for 2 yr (2003 & 2004) for four tillage treatments (CT-WE, KCC-WE, CT-HW, and KCC-HWE) in field experiments at the USVL, Charleston, SC

Source of variation	df	Spiders	Crickets	Earwigs	Click beetles	Rove beetles	Small ground beetles	Large ground beetles	Scarab beetles	Tiger deetles	Total insects[a]	Fire ants[b]
2003												
Tillage treatment	3	0.5	5.2*	3.2	0.3	0.3	7.3**	0.5	6.9**	5.8**	4.4*	2.1
Replication	4	0.3	1.9	2.5	0.4	0.5	1.1	0.2	2.7	2.1	1.4	2.5
Treatment × replicate	12	0.1	2.3	3.6	0.4	0.5	1.8	0.4	3.4	1.7	1.5	1.9
Contrast: conventional vs. KCC	1	0.2	4.1*	2.1	0.3	0.4	9.6**	0.2	1.1	6.3**	3.3	0.5
Contrast: weedy vs. hand weeded	1	0.2	2.8	2.4	0.1	0.4	2.1	0.3	7.6**	2.3	7.1**	2.8
2004												
Tillage treatment	3	1.3	4.9*	1.8	4.3*	5.2*	1.1	8.8**	2.5	4.1*	6.4**	4.2*
Replication	5	0.7	0.8	0.7	1.8	0.6	1.4	0.8	0.8	0.7	1.3	0.9
Treatment × replicate	15	1.6	0.9	0.7	1.5	1.2	1.4	0.7	1.0	0.8	0.9	1.0
Contrast: conventional vs. KCC	1	2.6	7.2**	0.2	4.2*	4.1*	1.9	7.1**	2.0	11.7**	0.1	0.4
Contrast: weedy vs. hand weeded	1	0.8	7.2**	0.3	0.0	0.1	1.4	12.7**	2.0	0.3	16.9**	12.1**

* Significant at the 5% level.

** Significant at the 1% level.

[a] Pitfall trap totals.

[b] Hot dog vial test.

Table 5. Average pitfall trap captures and fire ant collections in four tillage treatments of sweetpotatoes at the USVL, Charleston, SC, 2003 and 2004

Treatment	Spiders[a]	Crickets[b]	Earwigs[c]	Click beetles[d]	Small rove beetles[e]	Large ground beetles[f]	Ground beetles[f]	Scarab beetles[g]	Tiger beetles[h]	Total insects	Fire ants[i]
2003											
Killed-cover hand weeded (KCC-HW)	0.1 ns	3.1 ns	6.0 ns	0.01 ns	0.03 ns	0.45a	0.02 ns	0.9b	0.06b	11.3b	31.8 ns
Conventional tillage hand weeded (CT-HW)	0.0	3.8ab	4.6	0.01	0.01	0.14bc	0.02	0.1b	1.06a	10.8b	22.4
Killed-cover crop weedy (KCC-WE)	0.1	3.5ab	6.7	0.00	0.00	0.37ab	0.03	2.6a	0.08b	13.6ab	30.3
Conventional tillage weedy (CT-WE)	0.1	4.3a	7.4a	0.01	0.02	0.09c	0.02	2.9a	0.93a	16.5a	26.3
2004											
Killed-cover crop hand weeded (KCC-HW)	0.1 ns	1.5b	0.08 ns	0.17a	0.19a	0.07 ns	0.07b	0.02b	0.03b	2.6bc	90.7a
Conventional tillage hand weeded (CT-HW)	0.1	0.8b	0.22	0.02b	0.02b	0.02	0.08b	0.00b	0.37a	1.9c	76.8ab
Killed-cover crop weedy (KCC-WE)	0.1	2.5a	0.10	0.10ab	0.14a	0.12	0.23b	0.00b	0.05b	3.8ab	52.8bc
Conventional tillage weedy (CT-WE)	0.0	1.5b	0.08	0.08ab	0.05b	0.07	1.08a	0.12a	0.47a	4.3a	33.8c

Within each year, means in the same column followed by the same letter are not significantly different according to Fisher's LSD at the 5% probability level (SAS Institute 1999); ns, not significant.

[a] Not identified.

[b] Orthoptera: Gryllidae.

[c] Dermaptera: Forficulidae, primarily, *Forficula auricularia* L. (Weems and Skelley 1998).

[d] Coleoptera: Elateridae.

[e] Coleoptera: Staphylinidae.

[f] Coleoptera: Carabidae.

[g] Coleoptera: Scarabaeidae, primarily, *Phanaeus vindex* MacLachlan (Coleoptera: Scarabaeidae) (Harpootlian 2001).

[h] Coleoptera: Cicindelidae.

[i] *S. invicta.*

weedy plots. Click beetles captures were significantly higher in the killed-cover crop treatments in 2004. In 2003, large numbers of the generalist predator European earwig, *Forficula auricularia* L. (Dermaptera: Forficulidae) (Weems and Skelley 1998), were captured in pitfall traps, but there were no significant treatment differences in these captures. Overall, more crickets were captured in the weedy plots. Interestingly, trap captures of the scarab beetle *Phanaeus vindex* MacLachlan (Coleoptera: Scarabaeidae) were significantly higher in the weedy plots of both tillage treatments than in the hand-weeded plots (Table 5). This species is a large dung beetle (Harpootlian 2001) that was most likely attracted to decaying insects previously captured in the pitfall traps. Click beetles were the only pests that were significantly higher in pitfall traps in the killed-cover crop plots in 2004. These plots also had greater WDS damage, as the larvae of click beetles are the soil pest wireworms.

Discussion

In general, the three sweetpotato genotypes performed as well under the killed-cover crop system as they did under conventional tillage. However, hand weeding had much more impact on sweetpotato yields than did the type of tillage system used. The severe impact of weeds was not unexpected, because previous studies have shown that sweetpotato yield losses due to weed interference are acute when weeds are not controlled (LaBonte et al. 1999, Seem et al. 2003). The killed-cover crop production system may reduce but not prevent weed losses. The KCC-WE plots significantly out yielded the CT-WE plots only 1 yr (2002) of this study, which suggests that that weed interference can still negatively affect sweetpotato production in this alternate tillage system. Killed-cover crop mulches may be particularly useful in sustainable or organic production systems where weed control options are limited (Adam 2005). Legume cover crops are particularly valuable in organic production because they provide nitrogen, and meeting nitrogen requirements is sometimes difficult using organic fertilizer materials. Because sweetpotatoes require relatively low nitrogen fertilization rates, legume cover crops could potentially fulfill the crop's nitrogen needs.

This study and others (Bloodworth et al. 1995, Jett 1999, Stone et al. 2005, Treadwell 2005) indicate that killed-cover crop mulches can be used in sweetpotato production without causing increased insect damage or reduced yields. Overall, insect injury ratings for sweetpotatoes grown under killed-cover cropping mulch in this study were not greatly different from those grown in the conventional tillage system with the same weed control. For example, in 2003 there were no significant tillage effects on insect damage levels; and in 2002, the killed-cover crop plots actually had significantly less damage from WDS and flea beetles than the conventionally tilled plots. Only in 2004 was there significantly more damage from WDS and flea beetles in the KCC-WE than the CT-WE plots, whereas both hand-weeded treatments had similar pest levels. This indicates that any anticipated increase in insect injury to sweetpotatoes grown under a killed-cover crop mulch (Jett and Talbert 1997) did not occur in this study.

Our results are in agreement with a similarly designed experiment at the same location, in which Pullaro et al. (2006) found that the highest number of invertebrates captured in pitfall traps in bell pepper plots were in the killed-cover crop treatments. They also reported that predation of seeds and insects were increased in killed-cover crop plots of bell peppers and collards. Although Pullaro et al. (2006) attributed some predation to carabid beetles, they concluded that fire ants were the primary predators in this system. More fire ants were captured in the killed-cover crop treatments than in peppers plots on black plastic mulch. Similarly, we found increased numbers of predatory species in the killed-cover crop plots of sweetpotato.

In conclusion, the killed-cover crop mulch system seems to be a viable option for the production of sweetpotatoes. This tillage system minimizes soil erosion and reduces the impact of some weed species, while not adversely affecting yield or quality of the sweetpotato crop. Also, there was no greater overall impact of soil insect pests on sweetpotatoes grown in the killed-cover crop mulch as in conventional tillage. Certain beneficial predators also were enhanced in the killed-cover crop treatments.

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